

# Meeting with FCC Staff

Digital Radio Coverage and Interference Assessment Study

National Public Radio

Thursday, July 16, 2008

# Main Findings

- Wide variations in levels of IBOC coverage and analog interference per station
- 1% IBOC Assessments
  - Mobile coverage adequate, relative to analog
  - Indoor and portable coverage half of analog
- 10% IBOC Assessments
  - Mobile coverage increases to 17% over analog
  - Indoor coverage increases to 88% of analog
  - Large amounts of analog interference to some stations
    - Average of 26% loss in analog population covered
    - 41% of stations receive interference to 1/3 of service population

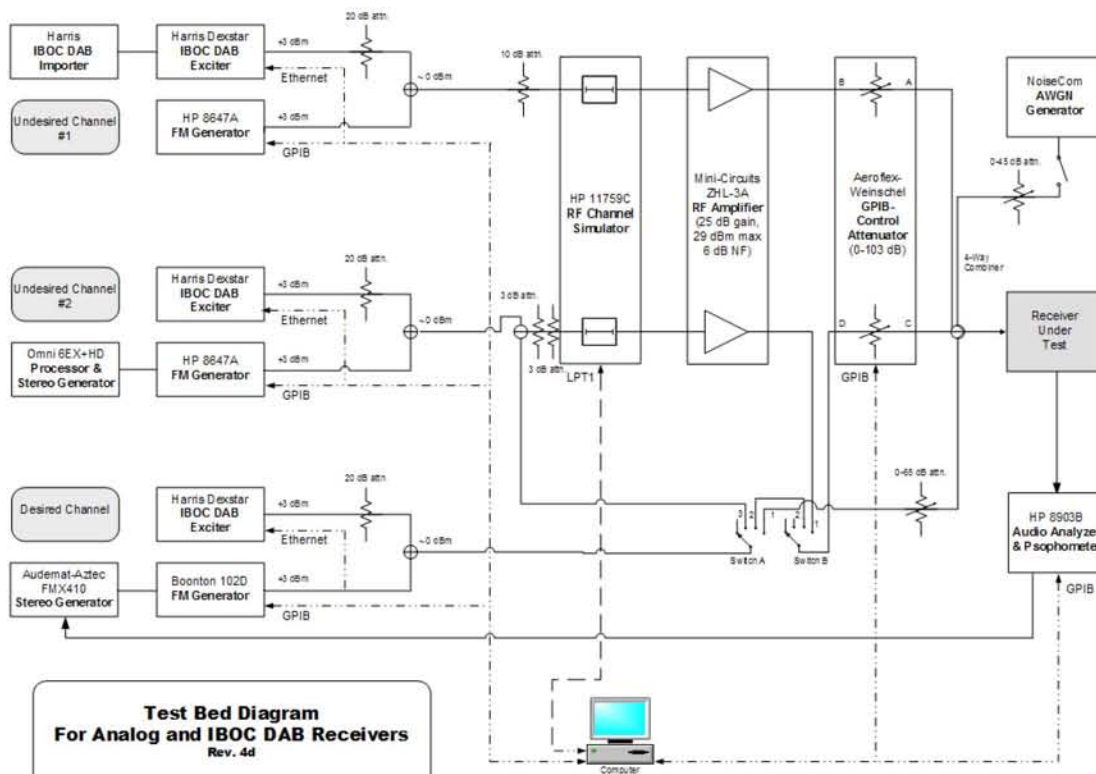
# Solutions and Next Steps

- Further lab and field testing of impact of elevated IBOC power, including subcarrier reading services
- R&D of
  - single frequency networks
  - Asymmetrical sidebands
  - IBOC directional transmission
- Development of a manageable regulatory policy to permit increased IBOC that protects analog FM service

# Receiver Test Bed and Laboratory

Examination of consumer radio performance

Extensive in scope and depth



NPR Labs - Washington, DC

# Comprehensive database of consumer receiver performance

## Analog-to-analog and hybrid-to-analog interference measurement

Analog  
Desired

### Sensitivity Tests

Analog Signal Analog Rcvr.		Hybrid Signal Analog Rcvr.		Hybrid Signal Hybrid Rcvr.
Mono	Stereo	Mono	Stereo	Unimpaired
Unimpaired	Unimpaired	Unimpaired	Unimpaired	30,000K AWGN
30 dB WQPSNR	30 dB WQPSNR	30 dB WQPSNR	30 dB WQPSNR	300,000K AWGN
40 dB WQPSNR	40 dB WQPSNR	40 dB WQPSNR	40 dB WQPSNR	
50 dB WQPSNR	50 dB WQPSNR	40 dB WQPSNR	50 dB WQPSNR	
30,000K AWGN	30,000K AWGN	30,000K AWGN	30,000K AWGN	
30 dB WQPSNR	30 dB WQPSNR	50 dB WQPSNR	30 dB WQPSNR	
40 dB WQPSNR	40 dB WQPSNR	30 dB WQPSNR	40 dB WQPSNR	
50 dB WQPSNR	50 dB WQPSNR	40 dB WQPSNR	50 dB WQPSNR	
300,000K AWGN	300,000K AWGN	300,000K AWGN	300,000K AWGN	
30 dB WQPSNR	30 dB WQPSNR	30 dB WQPSNR	30 dB WQPSNR	
40 dB WQPSNR	40 dB WQPSNR	40 dB WQPSNR	40 dB WQPSNR	
50 dB WQPSNR	50 dB WQPSNR	50 dB WQPSNR	50 dB WQPSNR	

Analog Interferer				Hybrid Interferer			
Co-Channel	1st Adj.	2 <sup>nd</sup> Adj.	3 <sup>rd</sup> Adj.	Co-Channel	1st Adj.	2nd Adj.	3rd Adj.
Mono	Mono	Mono	Mono	Mono	Mono	Single	Dual
-60 dBm	-50 dBm	-50 dBm	-50 dBm	-50 dBm	-50 dBm	Mono	Mono
-70 dBm	-60 dBm	-60 dBm	-60 dBm	-50 dBm	-60 dBm	-50 dBm	-50 dBm
Stereo	-70 dBm	-60 dBm	-70 dBm	-70 dBm	-70 dBm	-60 dBm	-60 dBm
-60 dBm	Stereo	Stereo	Stereo	Stereo	Stereo	-70 dBm	-70 dBm
-70 dBm	-70 dBm	-50 dBm	-50 dBm	-50 dBm	-50 dBm	Stereo	Stereo
	-60 dBm	-60 dBm	-60 dBm	-50 dBm	-60 dBm	-50 dBm	-50 dBm
	-70 dBm	-70 dBm	-70 dBm	-70 dBm	-70 dBm	-60 dBm	-60 dBm
						-70 dBm	-70 dBm

### Hybrid receiver interference

Hybrid  
Desired

Analog Interferer				Hybrid Interferer			
Co-Chan	1st Adj.	2nd Adj.	3rd Adj.	Co-Chan.	1st Adj.	2nd Adj.	3rd Adj.
-60 dBm	Upper=Lower	Upper=Lower	Upper=Lower	-60 dBm	-50 dBm	Upper=Lower	Upper=Lower
-70 dBm	-50 dBm	-50 dBm	-50 dBm	-70 dBm	-60 dBm	-50 dBm	-50 dBm
	-60 dBm	-60 dBm	-60 dBm		-70 dBm	-60 dBm	-60 dBm
	-70 dBm	-70 dBm	-70 dBm			Name Title	Name Title
	Variable Upper/Lower	Variable Upper/Lower	Variable Upper/Lower			Variable Upper/Lower	Variable Upper/Lower
	-50 dBm	-50 dBm	-50 dBm			-50 dBm	-50 dBm
	-60 dBm	-60 dBm	-60 dBm			-60 dBm	-60 dBm
	-70 dBm	-70 dBm	-70 dBm			-70 dBm	-70 dBm

## HD Radio receivers tested

Receiver Category	Brand	Description
auto adapter	AGT/Visteon	HD Zoom HDZ300
auto adapter	Directed Electronics	DMHD-1000
Car in-dash CD	JVC	KD-SHX900J
Car in-dash CD	Kenwood	KTC-HR100TR
Car in-dash CD	Panasonic	CQ-CB9900U
Car in-dash CD	Sony	XDR-S3HD
Auto/home transport.	AGT/Visteon	HD Jump HDP250
component tuner	Sangean	HDT-1
tabletop	Polk	I-Sonic
tabletop	Radiosophy	HD100

## D/U ratios for mobile receivers

40 dB Stereo WQPSNR	Analog -60 dBm	Analog -70 dBm	1% IBOC -60 dBm	1% IBOC -70 dBm
Cochannel	34	31	34	31
1 <sup>st</sup> -Adj.	-9	-8	12	10
2 <sup>nd</sup> -Adj.	-51*	-57	-50*	-57
3 <sup>rd</sup> -Adj.	-51*	-60	-50*	-57

# Consumer Receiver Measurements and IBOC Interference Susceptibility Ratios

## Analog Receiver Tested

Receiver Category	Brand	Description
Home stereo	Sony	STRDE697
Home stereo	Yamaha	HTR-5740
Home stereo	Denon	DRA-295
Home stereo	Denon	TU-680NAB
Home stereo	Pioneer	VSX-D814K
Shelf/mini system	Panasonic	SC-EN7
Shelf/mini system	Sony	CMTNE3
Shelf/mini system	Bose	Wave
Shelf/mini system	RCA	RS23035
Portable CD boombox	Panasonic	RXFS430A
Portable CD boombox	Aiwa	JAX-S77
Portable CD boombox	Grundig	S350
Portable CD boombox	GE	SuperRadio III
Portable CD boombox	CCRadio Plus	CCRadio Plus
Portable CD boombox	RCA	RCD147
Car in-dash CD	Pioneer	DEH-P6600
Car in-dash CD	Kenwood	KDC-3025
Car in-dash cassette	JVC	KS-FX490
OEM auto	Chevrolet	1995 Camaro
OEM auto	Chevrolet	2000 Tahoe
OEM auto	Chevrolet	2002 Suburban
OEM auto	Ford	2002 Mustang
OEM auto	Honda	2002 Accord
OEM auto	Honda	1997 Civic
Clock	Audiovox	CE256
Shelf/mini system	Panasonic	SA-PM19

## D/U ratios for indoor receivers

40 dB Stereo WQPSNR	Analog -60 dBm	Analog -70 dBm	1% IBOC -60 dBm	1% IBOC -70 dBm
Cochannel	34	34	34	34
1 <sup>st</sup> -Adj.	1	0	13	12
2 <sup>nd</sup> -Adj.	-45	-46	-32	-36
3 <sup>rd</sup> -Adj.	-47	-48	-38	-42

## D/U ratios for portable receivers

40 dB Mono WQPSNR	Analog -60 dBm	Analog -70 dBm	1% IBOC -60 dBm	1% IBOC -70 dBm
Cochannel	21	21*	18	16
1 <sup>st</sup> -Adj.	4	-1	0	-1
2 <sup>nd</sup> -Adj.	-38	-42	-22	-22
3 <sup>rd</sup> -Adj.	-42	-46	-35	-41

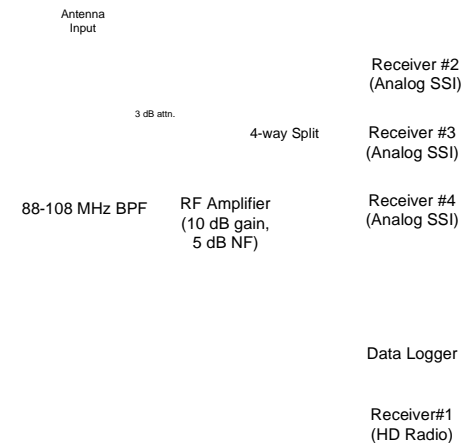
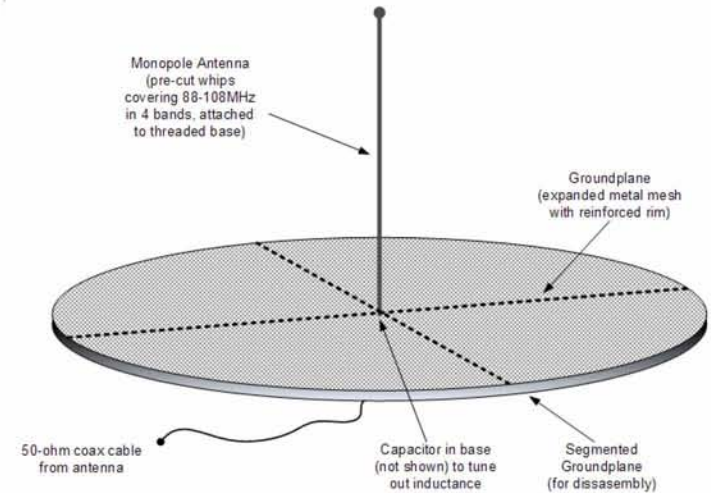
## Link Budgets for mobile, indoor and portable reception

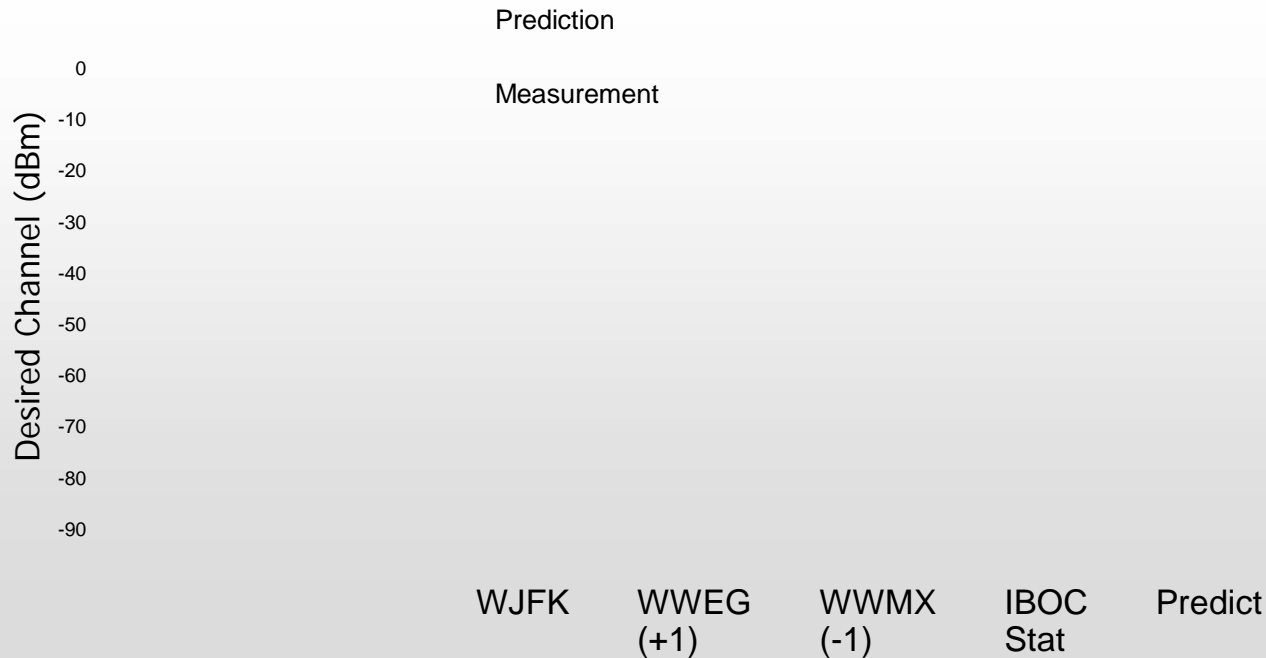
<i>k</i>	Boltzmann's constant	1.38E-23	W/K/Hz	Link Budgets for mobile, indoor and portable reception	
<i>T</i>	reference noise temperature	290	degrees K		
<i>B</i>	noise equivalent bandwidth of input of both carrier groups	140,000	Hz		
<i>Vi</i>	thermal noise of receiver bandwidth	-152.5	dBW		
<i>Nr</i>	noise figure of receiver input	-122.5	dBm		
<i>Cd/N</i>	minimum CNR for acceptable service (9-ray terrain-obstructed for TOA) (1.0% BER, urban fast fading, ref. Cd (dBm) to No (dBm/Hz))	6	dB		
	normalization of Cd/N to 1 Hz	57.3	dB-Hz		
	required input power	5.9	dB		
<i>IBACr</i>	1% IBAC ratio adjustment	-110.6	dBm		
	required analog host FM power	20	dB		
<i>f</i>	frequency of operation	-90.6	dBm		
<i>Kd</i>	dipole factor [ 20·log(9.73/(λ·G) ) ], where G=1.64	90	MHz		
<i>C</i>	dBm (50Ω) to dBuV conversion factor	7.2	dB	1.38E-23	W/K/Hz
	antenna gain relative to dipole (NPR data)	107.0	dB	290	degrees K
<i>L</i>	transmission line loss	-5	dB	140,000	Hz
<i>FPT</i>	incident field at 1.5m rcv. height	0	dB	-152.5	dBW
	<i>Nr</i> noise figure of receiver input, estimated	29	dBuV/m	-122.5	dBm
<i>Ne</i>	Environmental Noise-adjusted Field Performance Threshold per ITU-R P-372 model (noise above 470 MHz, urban fast fading, ref. Cd (dBm) to No (dBm/Hz)) F = c - 27.7·Log(f), where c = 76.8 (business)	7	dB	55.1	dB-Hz
	normalization of Cd/N from 1 Hz to <i>B</i>	3.6	dB		
	Normalization per ITU Report E-882-C, 10·log(1+Ne/Nr)	15	dB	-111.9	dBm
<i>FPTadj</i>	<i>FPTadj</i> = <i>FPT</i> + 10·log(1+Ne/Nr)	43	dBuV/m	20	dB
	required analog host FM power	91.9	dBm	Link budget for portable reception	
<i>f</i>	frequency of operation	90	MHz	1.38E-23	W/K/Hz
<i>Kd</i>	dipole factor [ 20·log(9.73/(λ·G) ) ], where G=1.64	7.2	dB	290	degrees K
<i>C</i>	dBm (50Ω) to dBuV conversion factor	107.0	dB	140,000	Hz
	antenna gain relative to dipole (BBC 1990, NPR data)	-15	dB	-152.5	dBW
<i>L</i>	transmission line loss	0	dB	-122.5	dBm
<i>LB</i>	building loss factor, 50th percentile, (single-story, 90 MHz, Skomal & Smith)	9	dB	8	dB
<i>Lf</i>	location variability factor (20% likely to exceed building loss)	8.4	dB		
<i>FPT</i>	incident field at 1.5m rcv. height	61.4	dBuV/m		
	normalization of Cd/N to 1 Hz	9.9	dB		
	required input power	-104.6	dBm		
<i>IBACr</i>	1% IBAC ratio adjustment	20	dB		
	required analog host FM power	-84.6	dBm		
<i>f</i>	frequency of operation	90	MHz		
<i>Kd</i>	dipole factor [ 20·log(9.73/(λ·G) ) ], where G=1.64	7.2	dB		
<i>C</i>	dBm (50Ω) to dBuV conversion factor	107.0	dB		
	antenna gain relative to dipole (BBC 1990, NPR data)	-20	dB		
<i>L</i>	transmission line loss	0	dB		
<i>LB</i>	building loss factor, 50th percentile, (single-story, 90 MHz, Skomal & Smith)	9	dB		
<i>Lf</i>	location variability factor (20% likely to exceed building loss)	8.4	dB		
<i>FPT</i>	incident field at 1.5m rcv. height	67	dBuV/m		

# Mobile Measurement System to validate lab studies and prediction models

## Public radio stations measured

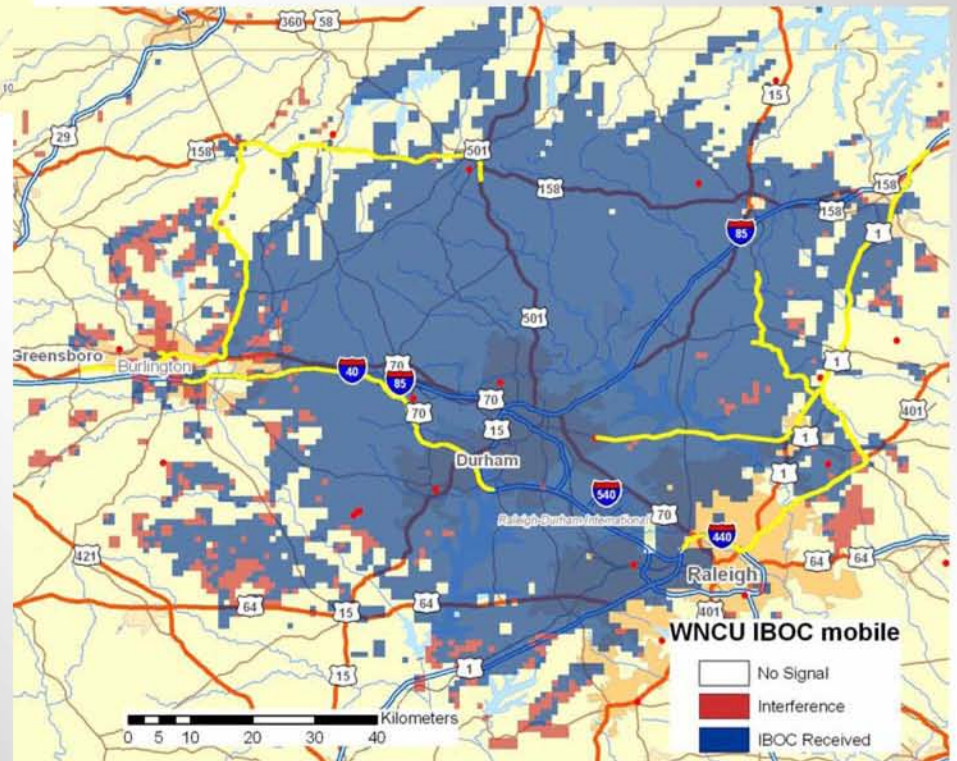
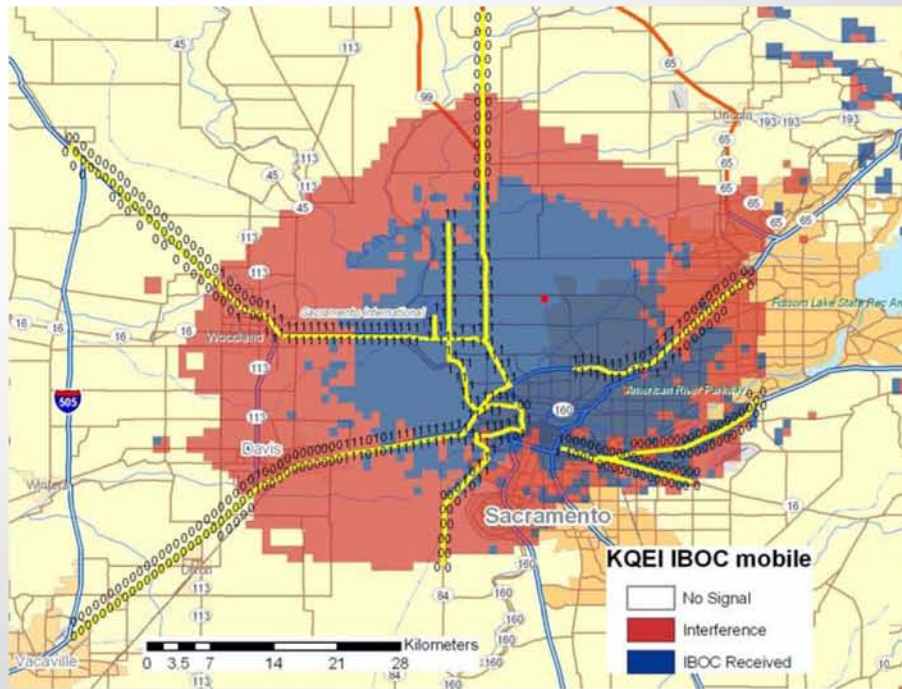
Call	Channel	City, State	Interference
WWFM	Ch. 206A	Trenton, NJ	30%
KMPO	Ch. 204B	Modesto, CA	28%
WMUB	Ch. 203B	Oxford, OH	26%
KQEI-FM	Ch. 207A	North Highlands	23%
KVPR	Ch. 207B	Fresno, CA	14%
WNCU	Ch. 214C2	Durham, NC	14%
KXPR	Ch. 205B	Sacramento, CA	8%
WFYI-FM	Ch. 211B	Indianapolis, IN	4%
WHRV	Ch. 208B	Norfolk, VA	3%
WBEZ	Ch. 218B	Chicago, IL	0%



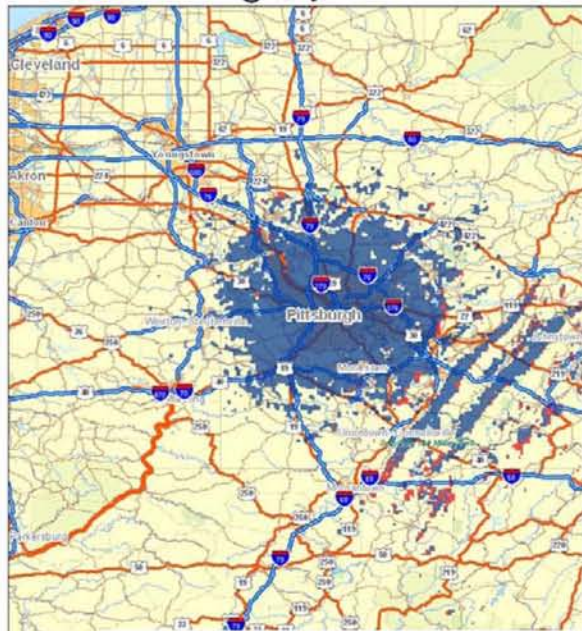


- Verification of IBOC DAB Coverage Prediction Model
  - For 10 public radio stations and 1 commercial station
    - Model accurately predicted reception between 85% and 95% of all samples
    - Typically less than 5% false positive and false negative predictions
- Developed map prediction software to predict coverage of all 850 public radio stations

IBOC DAB Prediction Model applied to 850 public radio stations, 75 stations studied in detail

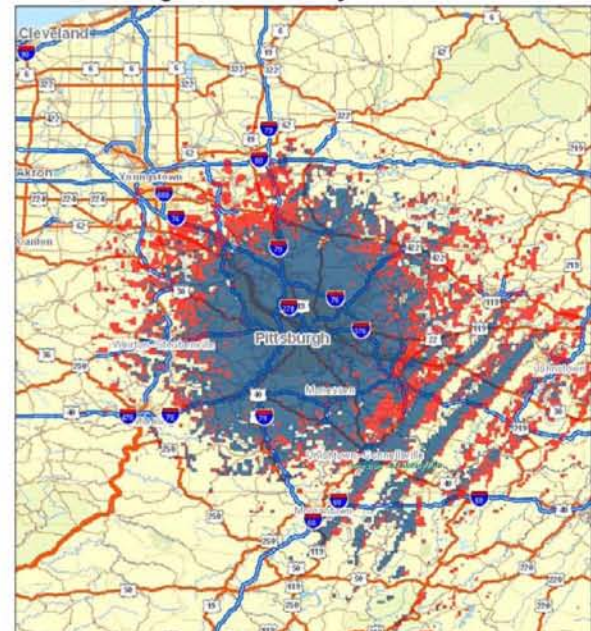


WDUQ - IBOC - Mobile @1% hybrid

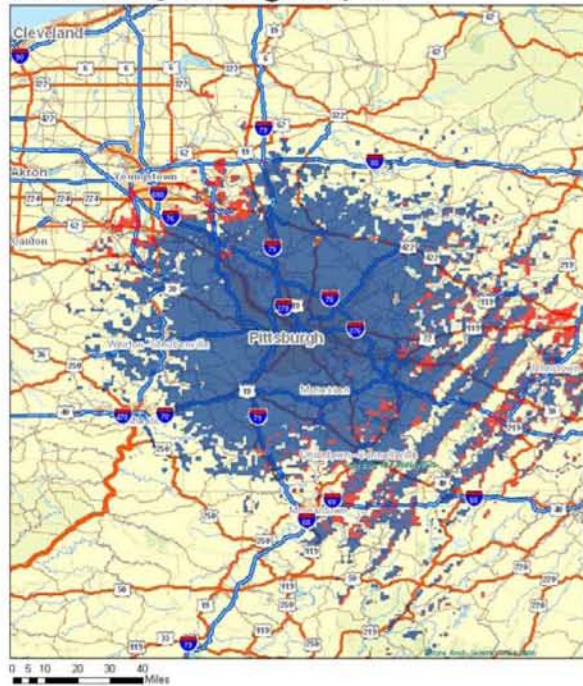


IBOC and Analog  
Coverage at 1%  
hybrid

WDUQ - Analog - Mobile w/1% hybrid



WDUQ - IBOC - Mobile @10% hybrid



IBOC and Analog  
Coverage at 10%  
hybrid

WDUQ - Analog - Mobile w/10% hybrid

